Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science

Claw and leg lesions in preweaning piglets - a comparative study of piglets reared on structured polyurethane coating and piglets reared on concrete floors

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Claw and leg lesions in preweaning piglets - a comparative study of piglets reared on structured polyurethane coating and piglets reared on concrete floors

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- en jämförande studie på smågrisar uppfödda på golv med mönstrad polyuretanbeläggning och smågrisar uppfödda på betonggolv

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Preface

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Abstract

Floor surface in pig facilities can have an impact on animal welfare and pig health, as it can cause the pig physical damage and thereby an increased risk of infectious diseases and lameness. The development of pig housing systems has resulted in a decreased use of bedding. It seems hard to find the optimal floor in farrowing pens, as it must suit both the sow and piglets. The floor friction needs to be adequate to avoid slips and at the same time should the floor be non-abrasive. Abrasions and lesions caused by the floor are not only causing the animal suffering, but are also negative from an economical aspect. A soft polyurethane coating with a profile in pens with nursing piglets was tested and compared with a concrete floor, as the soft floor theoretically should be gentler toward piglets' claws and legs. To avoid injuries caused by slips, a structured surface profile to increase the friction and floor grip of the polyurethane material was added. Damage scoring was done on preweaning piglets and in total 247 piglets was examined. Piglets reared on polyurethane material did have soles that were sharp edged, while concrete gave rounded soles ($p<0.01$), but besides that, no significant differences in prevalence of damaged soles and soft heels could be detected. The polyurethane material gave however the lowest damage scores on hocks ($p<0.05$). The scores of knee damage were similar regardless which floor material the piglet was reared on.

Laboratory and field studies were done on the different floor materials to obtain technical values of friction and floor abrasiveness. The abrasive test resulted in the conclusion that concrete is more abrasive than polyurethane, regardless structure of the polyurethane coating. The friction test gave the conclusion that the polyurethane material in this study has the static friction coefficient (SCOF) and dynamic friction coefficient (DCOF) means similar to those of concrete.

Sammanfattning

Golv i grisningsstallar kan ha en stor påverkan på djurvälfärden och på grisarnas hälsa, då viss golvutformning kan orsaka grisen fysisk skada och därmed öka risken för infektionssjukdomar och hälta. Vidare har utvecklingen av moderna produktionssystem till grisar resulterat i att användningen av strö och halm har minskat. Det är svårt att hitta det optimala golvet för grisningsboxen, eftersom det ska passa både suggan och hennes smågrisar. Golvets friktion måste vara tillräcklig för att undvika halkskador, samtidigt som det ska ha en låg avnötningsgrad för att minimera avnötningen på smågrisarnas klövar och ben. Skavsår och skador som orsakats av golvet medför inte bara lidande för djuret, utan är även negativt sett ur ett ekonomiskt perspektiv. I denna studie testades ett betonggolv med en mjuk polyuretanbeläggning och jämfördes med ett vanligt betonggolv. Hypotesen var att det mjuka golvet ur ett teoretiskt perspektiv bör vara snällare mot smågrisens klövar och ben. På polyuretanbeläggningens yta gjordes ett mönster för att öka materialets friktion och golvgreppet och på så sätt undvika halkskador. Skaderegistrering utfördes på ej avvanda smågrisar och 247 smågrisar undersöktes totalt. De smågrisar som växt upp på polyuretanbeläggning hade vid undersökningen signifikant större andel sulhorn som var fortfarande var vassa ($p<0,01$) medan betong gjorde att sulhornen var rundade. Förutom detta

kunde inga skillnader mellan de två golvtyperna på registrerade skador på sulhorn och ballhorn ses. Däremot gav polyuretanbeläggningen en lägre skadepoäng för hasskador ($p<0,05$). Skadepoängen för knän och kotor var dock densamma oavsett vilket golvmaterial smågrisen var uppfödd på.

Laboratorie- och fältstudier gjordes på polyuretanbeläggningen för att erhålla ett tekniskt värde på golvets friktion och avnötningsgrad. Avnötningstesten gav slutsatsen att betong är mer avnötande än vad polyuretanbeläggning är, oavsett vilket mönster polyuretanbeläggningen har. Friktionstesten gav resultatet att det studerade polyuretanmaterialet, oavsett mönster, hade en statisk friktionskoefficient (SCOF) och en dynamisk friktionskoefficient (DCOF) motsvarande dem för betong.

1 Introduction

The animal management and the animal welfare standards in Sweden are stricter than in most other countries, due to the Swedish animal welfare concept. For example, sows in crates and fully slatted floors in farrowing pens have been banned in Sweden for many years in respect for the animal welfare. However, some health issues in the pig production are still a problem in Sweden. Lameness in piglets is one of the major welfare problems in Sweden and is resulting in economic losses in form of dead pigs, decreased growth, costs of antibiotic treatments and additional work. Injuries on the piglets' legs and claws, which are caused by the floor has been a problem for decades and still remains a problem today.

A pig's hoof is created to withstand wear and movements (Jordbruksverket, 2006) but there is a big difference between floors in the modern pig industry and a pig's natural habitat. Today abrasions especially over carpus can be seen in virtually all piglets at three days of age (SVA, 2009). The use of bedding and straw has declined with the development of intensive rearing systems and together with the floor structure, its surface and condition, these factors can have a major impact on the welfare and health of a pig herd (KilBride et al., 2009a).The pain and discomfort that damage to claws and legs causes, leads to piglets that become less active and spend more time lying down compared with unaffected piglets (KilBride et al., 2009a). Furthermore will claw and leg damages increase the risk of infections and lameness, as micro-organisms will enter the blood stream easier (Ehlorsson et al., 2002; Kilbride et al., 2009a; SVA, 2009).

Floors in animal facilities must withstand a strong pressure. A resistant floor requires low maintenance and a long life span (Jordbruksverket, 2006) and the requirements of floors in farrowing pens are especially high as it must suit both the piglets and the sow. In addition to that, both chemical and mechanical load places high demands on the flooring material (Määtää et al., 2009). The floor surface in a farrowing pen must have adequate friction to avoid slips and at the same time being non-abrasive (Jordbruksverket, 2006; von Wachenfelt, 2009). It is also favourable to have a floor surface that is easy to clean and also have a short drying time (Jordbruksverket, 2006).

The aim of this thesis was to investigate if there are any differences in claw and leg damage in average in litters reared on concrete and polyurethane coating respectively. The aim was to identify large differences in the piglets' leg health status between the floor types and therefore was the gender and weight of the piglets not regarded to be of importance in this study.

2 Hypothesis

The hypothesis of this study was 1) that a soft floor with profile polyurethane in farrowing pens gives less abrasions and lesions in preweaning piglets than a concrete floor and 2) that the structure in the polyurethane material gives adequate grip and friction, preventing the sow and piglets from slipping and thereby reducing slip- and fall-related injuries like crushed piglets and splay legs.

3 Literature study

3.1 Anatomy

3.1.1 The biology of the pig hoof

The pig's hoof is relative similar to those of cattle. A pig's hoof is however not bent inward at the front but straight and the hoof has a soft digital pad which a cattle hoof lacks (Sack, 1982). A pig has two toes and two accessory digits on each hoof (Figure 1).

The hoof of a pig has a complex structure with bones, tendons and ligaments as central parts (Geyer & Tagwerker, 1985; Jordbruksverket, 2006). The outer part of the hoof is called the sole horn and is separated from the heel horn with the white line. A pig's hoof consists of several parts (Figure 2). The subcutis in the soft heel serves as a cushion when the hoof lands on the ground (Geyer & Tagwerker, 1985). The subcutis and the corium consist of connective tissue and are very sensitive. If the subcutis and corium becomes damaged, it will cause the pig a lot of pain, as this part of the hoof contains blood vessels and nerves (Geyer & Tagwerker, 1985; Jordbruksverket, 2006; Sjaastad, 2003). Epidermis on the other hand, contains no nerves or blood vessels and is therefore totally insensitive. The epidermis consists of epithelia cells and can be divided into a soft part and a cornified part (Geyer & Tagwerker, 1985; Sjaastad, 2003).

Figure 1.A piglet´s claw with sole horn, heel horn and accessory digits.

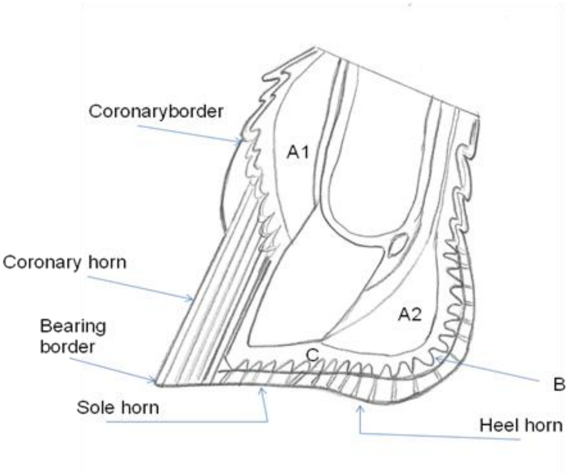


Figure 2. Schematic longitudinal picture of a pig claw.
A1: subcutis in the coronet; A2: subcutis in the soft heel;
B: soft part of epidermis; C: corium. Source: Geyer & Tagwerker, 1985; Jordbruksverket, 2006

3.1.2 Hoof growth

The hoof growth varies significantly with age in pigs. An adult sow has a growth of approximately 5-6 mm/month, while the growth of a slaughter pig's (20-100 kg) claw is approximately 10 mm/month (Geyer & Tagwerker, 1985; Jordbruksverket, 2006). It is important that the wear of the claw is the same as the growth. If the growth of the claw is more than the wear, it may lead to overgrown and deformed claws (Geyer & Tagwerker, 1985). If the wear is exceeding the growth, abrasions will occur (Jordbruksverket, 2006).

3.1.3 The preweaning piglet

Injuries and lesions to piglets' legs and claws are common problems in the piglet production. Newborn piglets are particular vulnerable due to their soft feet and legs (KilBride et al., 2009b) and the water content of both the tissue and claws is high after birth (Westin et al. 2008). Injuries arise particularly during the nursing period due the competition between piglets when they are establishing the teat order (Kyriazakis & Whittemore, 2006). During the first nursing phase the piglets jostle to find their own teat and then they start to massage the udder (Kyriazakis & Whittemore, 2006). The roughness of the floor surface may develop lesions during the suckling period (Zoric et al., 2008) and these lesions are results from repeated rubbing of skin and claws against the floor (Jordbruksverket, 2006; Mouttotou et al., 1999). When the piglets are trying to access the udder during the massaging phase, they are making paddling movements and when slips occur this action causes abrasions (Jordbruksverket, 2006; Mouttotou et al., 1999). The pig's claws and limbs are getting harder with age (KilBride et al., 2009b) and Mouttotou & Green (1999) suggest that by providing a soft surface (paper, straw, mats) during the piglets' first week of life until the horn of the claws becomes harder and more resistant, it is possible to protect the piglets' claws. They stress that this may reduce or even prevent lesions.

3.2 Injuries and infections

About every tenth piglet in Sweden is today treated with antibiotics (SVA, 2009) and about 75-85 % of these are treated during the three first weeks of life (SVA, 2009; Zoric & Wallgren, 2008). The prevalence of injuries to claws and legs in piglets vary by age, floor condition and floor type (Kilbride et al., 2009b). Lameness in piglets is a major welfare problem in Sweden (SVA, 2009) and the floor may contribute to infections when the protecting barriers of the skin are broken, due to damage caused by the floor (Baxter, 1984). Open portals through injuries in claws and legs make it easier for micro-organisms to enter and cause infections (Baxter, 1984; Ehlorsson et al., 2002; Kilbride et al. 2009a; SVA, 2009). Smith (1991) stress that if swelling around claws and joints becomes chronic, the response to treatment might be poor. The most observed site on the body to have lesions is the knees (Penny et al., 1971; Zoric & Wallgren, 2008). Zoric et al. (2009) noticed a reduction in incidence of sole bruising, abrasions and lameness of piglets that received double the amount of straw (2 kg/sow and 2 hg/piglet per day) compared with the control amount (1 kg/sow and 1 hg/piglet per day). It has been found that injuries to the forelegs generally are more common than injuries to the hindlegs (Bengtsson et al., 1982; Fajersson, 1982). Other common sites where injuries have been observed are in the following order: fetlock, hock, elbow and coronet (Penny et al., 1971). Moreover can damage to teats caused by rough floor surface be seen in piglets. Penny et al (1971) noticed that females often got more teat damaging than males and that it is often the first three pairs of teats that are affected (Penny et al., 1971).

The floor's overall damage potential is dependent on the contact surface between the floor and animal's body parts such as feet, knees, shoulders etc. (Jordbruksverket, 2006; Zoric & Wallgren, 2008) and if the power of a strain is exceeding the tissue strength, it produces a physical damage (Zoric & Wallgren, 2008).

3.2.1 Gradual development of lesions

Many studies have come to the conclusion that lesions in piglets develop gradually. Mouttotou & Green (1999) and Zoric et al. (2004) found that piglets had mild skin lesions and lesions of sole bruising shortly after birth. These lesions later developed into moderate lesions between 3 to 10 days of age and from day 10 to 20 days of age the lesions became mild again (Mouttotou & Green, 1999; Zoric et al., 2004). In the study by Mouttotou & Green (1999), severe sole bruising was uncommon but in cases where it was observed, the piglets were between 2 and 7 days of age. Mouttotou & Green (1999) found that 217 of 356 (61 %) examined piglets (reared on solid concrete and plastic slats) developed sole bruising within 24 hours. This proportion increased to 100 % during the nursing period (Mouttotou & Green, 1999).

3.2.2 Affecting the animal welfare and the production

The interior design in animal facilities should be constructed in such way that it does not cause the animal damage or endanger animal health (SFS, 1988:539). The welfare of piglets is partly depending on the floor quality, mainly because lesions and abrasions may lead to lameness and pain (Zoric et al., 2008). Mouttotou & Green (1999) claim that piglets with sole erosions and sole bruising spent less time suckling in general. They also noticed that these piglets were less active than the rest and spent more time lying, instead of standing, fighting, walking and playing. KilBride et al. (2009a) stress that piglets with injuries on claws and legs only performed necessary activities like feeding and drinking but no playing. Mouttotou & Green (1999) and KilBride et al. (2009a) came to the conclusion that the less active behaviour was a result from lesions being painful. Besides animal suffering, lameness gives economic losses like dead piglets, increased labour, increased use of antibiotics and decreased growth (Zoric, 2008; Zoric et al., 2008). There may also be losses of production later on if gilts that were supposed to be used as replacement sows are rejected at selection because of leg damage or damaged teats (Walton, 1991). Ziron & Hoy (2003) noticed a decreased growth in piglets with knee damages and they found that piglets with no knee damages had a greater live weight gain at each weighing (day 21 and day 28 of life) than piglets with damages on their knees. Mouttotou & Green (1999) found that piglets that developed sole erosions and sole bruising the first day of life were significantly heavier than piglets without these disorders at day one. They suggested that it is a result of that the digits of the heavier piglets are carrying a heavier load.

3.3 Floors in animal facilities

3.3.1 Different types of floors

The floor in a pig’s natural habitat differs a lot from the floor in a modern piggery and the management of the pig does not always suit the pig’s need (Baxter, 1984). The requirements of a good floor in animal facilities can be summarized as following: the floor must not cause the animals’ pain, diseases, injuries or discomfort. Magnusson (1995) stated some other factors that influence the floor’s design and the factors are mainly describes as:

- Thermal comfort
- How the floor affect the hygiene and animal cleanness
- Cleanability of the floor
- How rough and soft the floor surface is
- Risk of slips
- Ammonia emission
- Durability
- Economy

Concrete is today the most frequently used material in pig facilities (Bengtsson et al., 1982; Baxter, 1984). The three most common types of concrete floors in animal facilities are: single-layered, bi-layered and insulated floorings (Nilsson, 1996). It is important to have high knowledge of concrete construction in order to adjust the floor to its requirements. The mechanical and chemical stress to which the concrete is exposed is limiting the durability of the floor (Määtää et al, 2009).

When calculating the economical value of different flooring alternatives, it is important to reconsider all factors affected; animal welfare, production, labour and costs of bedding material (Magnusson, 1995). Some floors cannot cope with all requirements and therefore extra material like sawdust, straw and wood shavings have been added to fulfil the requirements (Baxter, 1984). Deep straw beddings are similar to the substrate and ground pigs finds naturally (Arey, 1993) but unfortunately the use of straw has disadvantages as well, like higher production cost and risk of contamination with fungi, growth of bacteria and pathogens (Tuyttens, 2005). Besides, straw is generally incompatible with slatted floors and liquid manure systems (Tuyttens, 2005).

When designing and making the choice of floors in animal houses a number of different factors need to be considered. These factors can be grouped under three categories which are interacting (Figure 3) (Baxter, 1984). The primary interacting elements are: the animal, the floor and the residues, like faeces, urine, feed and water (Baxter, 1984).

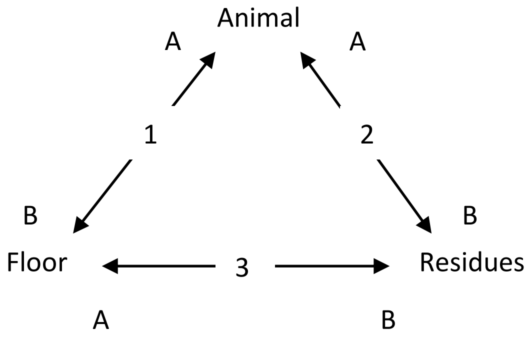


Figure 3. The interacting between an animal, the floor and the residues.

1A: The effects of the floor on the animal
1B: The effects of the animal on the floor
2A: The effects of the residues on the animal
2B: The effects of the animal on the residues
3A: The effects of the residues on the floor
3B: The effects of the floor on the residues

It may be necessary to change the floor structure if any of these interactions is incompatible with the requirements (Baxter, 1984).

3.3.2 Surface treatments

There are a number of different ways to treat the surface of a concrete floor. Jordbruksverket (2006) mention three; mechanical treatment, chemical treatment and a protective treatment. A mechanical treatment changes the surface profile by making it smoother or rougher and it is a cheap way of doing it. A chemical treatment can be done on slippery concrete floors as the acid is corroding the concrete floor making the surface more structured. When protective treatment is used, the mechanical and chemical resistance is improved (Jordbruksverket, 2006). The protection treatment is generally done by a curing compound for concrete usually silicate or fluat, and/or with a hardening mass consisting of epoxy, polyurethane, polyester or acryl (Jordbruksverket, 2006; Nilsson, 1996).

3.3.3 Prevalence of abrasions and injuries on different floors and beddings

Gravås (1979) studied physical effects on both piglets and sows and compared three different floor surface treatments; concrete covered with rubber mats, untreated concrete and epoxy-painted concrete. The rubber floor which was intended to be comfortable gave the highest incidence of wounds with the largest diameter, while the smallest wounds occurred on concrete floor. The epoxy gave an intermediate result (Gravås, 1979). Bengtsson et al. (1982) and Fajersson (1982) studied leg injuries of piglets reared on three different floor types; plastic coated woven wire, galvanized perforated metal and solid concrete with straw bedding. The concrete floor gave the highest incidence of piglets with leg injuries the first 10 days of age, whereas at day 21 days of age did the plastic coated woven wire give the highest incidence of leg injuries.

Mouttotou et al. (1999) noticed that piglets kept on sparse wood shavings had more skin abrasions than piglets kept on no bedding. The reason behind this can be that the wood shavings are moving when the piglets are making paddling movements during suckling. It is possible that the wood shavings penetrates and scuff the skin instead protecting it (Mouttotou et al., 1999). Zoric et al. (2008) found that most severe abrasions at soles and carpus could be seen when a new solid concrete floor with slatted floor was used. They also found that deep litter system with peat gave the lowest incidence of abrasions (Zoric et al., 2008).

3.3.4 Repairing the floor

Repairing concrete floors is sometimes necessary, as the floors surface characteristics changes by time (Baxter, 1984). The repairing process may seem expensive but it will improve the animal health (Jordbruksverket, 2006). Zoric et al. (2009) studied abrasions and lameness in piglets caused by floorings and noticed the importance of repairing rough and rugged concrete floors. They saw a significant decline ($p<0,001$) in incidence of abrasions at carpus at 3 days of age when the concrete floor had been repaired. Floor surfaces often changes differently for different materials (Baxter, 1984). The shape of the sand and aggregate which the concrete is made of, have a great impact on the floor roughness when the surface has been removed. In the original concrete an exposed surface made of round aggregate and sand with round grain structure will be smoother than concrete made of crushed stone aggregate and sharp sand (Baxter, 1984).

3.3.5 Cleanability and drying time

The floor requirements in farrowing pens often contradict each other. The floor surface must have adequate friction without being abrasive at the same time. The floor should also be easy to clean and have a short drying up time (Jordbruksverket, 2006). This is important, both from labour- and from hygiene aspects. The well-being of animals is well linked with the cleanability of floorings (Määtää et al., 2009). They noticed a decrease in cleanability of all materials that had been affected by mechanical wear. Concrete is frequently used in animal facilities (Baxter, 1984; Bengtsson et al., 1982) and Määtää et al. (2009) stress that due to the wearing of concrete, there is a need of finding alternatives like surface coating and other improvements of concrete surfaces. Concrete is a porous material and to decrease the penetration of the water into the concrete, coating can be used (Määtää et al., 2009). Garcimartín et al. (2008) noticed for example that resin floors were easier to clean compare with concrete floors. Puumala et al. (2005) measured cleanness of different floors and concluded that the cleaning time of plastic floors was significant shorter than floors made of concrete. The ease of cleaning, measured in m^2/h, was 15-40 in concrete (new surface) compared with 120 in polyurethane compounds (Puumala et al., 2005).

3.4 Floor properties

3.4.1 General

There are five factors that contribute to the total injury potential of a floor and they are mainly described as slip-resistance (friction), abrasiveness, surface profile, hardness (McKee & Dumelow, 1995) and thermal properties (Webb & Nilsson, 1983). All these factors are connected to one another. If there is a change in the surface profile for example, there will most likely also be a change in both the friction and the abrasiveness (McKee & Dumelow, 1995).

3.4.2 Friction

Friction occurs between two surfaces that are in contact, for example, between the hoof and the floor (Jordbruksverket, 2006) and the reason for measuring the friction is to prevent slipping and tripping injuries (von Wachenfelt, 2009). The friction in soft floors is generally higher than in hard floors (Jordbrukverket, 2006) and if the floor is wet or manure covered, friction declines (Baxter, 1984; Jordbruksverket, 2006; von Wachenfelt, 2009). A slippery floor can cause major damage and injuries to pigs (Gregory, 2007) causing wounds and splay legs (Jordbrukverket, 2006; Magnusson, 1995). Zoric (2008) claim that splay legs along with polyarthritis and skin abrasions are the most common conditions affecting the locomotor system of piglets.

Floors in farrowing pens need to be soft but with a sufficient grip to make the sow comfortable enough to lie down and stand up without slipping or scraping her knees (Gregory, 2007). Gregory (2007) states that in cases where piglets are crushed by the sows generally occurs when the sow lies down. When the friction of the floor is insufficient the sow may have difficulties controlling the way she lies down. There is an increased risk that the sow will crush her piglets if she slips, as she lies down faster (Gregory, 2007).

There are some different testing devices to measure the friction of the floor. The friction can be measured with a British Pendulum Tester or Ski Resistance Tester (SRT) (Figure 11) (Jordbruksverket, 2006; Nilsson et al., 2008; von Wachenfelt, 2009). The measurements are given in “British Pendulum Number” (BNP) (Jordbruksverket, 2006). This measure device is using a dynamic pendulum (Jordbruksverket, 2006; Nilsson et al., 2008) and measuring the energy loss when the rubber slider at the end of the pendulum is propelled over the floor (Nilsson et al., 2008). Jordbruksverket (2006) suggest that the friction of a wet surface in farrowing pens should be at least 80 BNP according to the SRT- method. Another way to measure the friction is by a drag method. A coefficient of friction expressed by calculating the ratio between the pulling force and the normal force (Nilsson et al., 2008). A static friction coefficient (SCOF), when the body is at rest and a dynamic friction coefficient (DCOF), when the body is moving are determined (Nilsson et al., 2008; von Wachenfelt, 2009).

3.4.3 Abrasiveness

A floor's abrasiveness is often linked to the friction of the floor (Jordbruksverket, 2006). Zoric et al. (2008) noticed that new concrete floors gave more abrasions at carpus and soles, than old concrete floors. The method used when measuring the abrasiveness of a floor includes a plaster test body. This method has been developed at the Department of Rural Buildings, Alnarp and is described by Nilsson (1988). A plaster block is dragged a specific distance over the test floor and the difference in weight is calculated by knowing the weight of the plaster block before and after the dragging test. The difference is representing the abrasion of the floor (Nilsson et al., 2008). Jordbruksverket (2006) suggest that the abrasion in a farrowing pen should not be more than 5 grams/meter, according to this method.

3.4.4 Surface profile

Floors with sharp edges can cause high stress in the underlying tissue which later can develop into injuries (Webb & Nilsson, 1983). Webb & Nilsson (1983) also stress that slatted floor can have the same effect as sharp edges due to high pressure of the hoof, if there is a small surface to void ratio.

3.4.5 Hardness

The importance of a soft floor is higher for large animals than it is for small animals, due to larger contact pressure to the lying area (Nilsson, 1988). Telezhenko et al. (2007) reported that the majority of dairy cows preferred to stand and walk on soft rubber floor rather than concrete floors. Rubber mats in cubicles for cows has been used for many years and in a study by Nilsson (1988) the cows preferred the softest floor choice (15 cm sawdust). Gravås (1979) concluded that rubber mats for sows are good from a lying-comfort aspect.

3.4.6 Thermal properties

Injuries such as burns or frost bites can directly be caused by extreme temperature (Nilsson, 1988). The floor can also be a way for the animal to control their own heat loss by lying down, which can be beneficial in hot conditions. The floor can however be a cause of thermal discomfort in cold conditions (Baxter, 1984). Between 8 and 20 % of the pig's body can have contact with the floor while lying down (Baxter, 1984). Insulation such as straw bedding and the thermal resistance of the floor has a great impact of the conservation of the heat loss. Baxter (1984) states that if a floor's thermal resistance is higher than 0.12 $°Cm^2/W$ it will conserve the heat loss and thereby feel warmer.

3.5 The farrowing pen

Injuries in preweaning piglets are commonly linked to damage caused by concrete floors. The floor in a farrowing pen needs to fulfil different varieties of requirements, both the requirements of the large sow and the small piglets. Sows need a comfortable lying area, sufficient space and a floor with enough friction to avoid slips (KilBride et al., 2009b). Piglets on the hand need a soft, non abrasive, flat floor that is well insulated (Jordbruksverket, 2006; Zoric & Wallgren, 2008). The farrowing pen must be sturdy to withstand the sow's size and weight (KilBride et al., 2009b). Normally, there will be a compromise between these requirements and it seems to be impossible finding the optimal indoor floor (KilBride et al., 2009a).

In Sweden, floors in modern farrowing pens often consist of an area made of solid concrete and one section drained floor. In Sweden the lactating sow must have a total floor area of minimum 6 m^2, with at least three fourth of the lying area consisting of solid floor (SJVFS 2010:15). The remaining lying area may consist by drained floor, with a maximum gap width of 11 mm and a slat width of minimum 11 mm (SJVFS 2010:15). If the drained floor consists of concrete, the slat width needs to be at least 80 mm (SJVFS 2010:15). Slatted floors with sharp edges and too wide gaps often causes wounds at the coronary border and the wound may even pierce into the corium (Geyer & Tagwerker, 1985). Gregory (2007) stated that to avoid foot abrasions, the edges of slats should not be sharp or chipped. Cast-iron does not usually cause any problems according to Gregory (2007). The problems with metal slats often occur when they brake and sharp edges are developed (Gregory, 2007). Gregory (2007) also claims that plastic slats most often tend to be gentler than metal slats, but that plastic slats also are more noisy and slippery. It is preferred to have a good surface profile if plastic slats are use, to provide a good grip (Gregory, 2007).

4 Materials and methods

4.1. Experimental plan

Floors with profiled polyurethane coating were compared with concrete floors in farrowing pens. The study was divided into two parts, one part recording lesions on piglets' claws and legs and the second part consisted of floor measurements. The floor measurements included friction and abrasive tests.

The first part of the study was carried out at LBT's Odarslöv's Research Farm. The sows were a Swedish/Norwegian Landrace X Yorkshire cross and inseminated with a Hampshire boar. To determine the effect of flooring, three pens had polyurethane coatings and the other pens were original concrete floor. The study was carried out during 2011 for a total of 4 batches. In each batch, there were three sows with their litter on the testing floor and one to three sows with their litter on the original concrete floor. In total were there 247 piglets used in the study, 131 piglets (12 litters) reared on polyurethane coating and 116 piglets (10 litters) reared on concrete.

The second part of the study was carried out as mainly a laboratory study. Two different profile coating structures were tested. One floor that was structured by using corrugated board and one by using straw to construct a structure in the wet polyurethane mass (Figure 7A-D). Both the corrugated and the straw structured polyurethane coatings were tested. A SRT test was done on the corrugated profile, as the friction could differ depending on in which direction the friction was tested, transverse the grooves or in the same directions as the grooves. Therefore were both directions tested separately with the SRT test device. All friction tests were laboratory studies. The abrasion test however was done as a field test on the floors in the farrowing pens used in the first part of this study, at LBT's Odarslöv's Research Farm.

4.1.1. The farrowing pens

Farrowing at the research farm took place in three farrowing units with eight pens in each unit. The farrowing pens (Figure 4) were located in two rows with an inspection alley in the middle. Each pen had an area of 7.0 m^2 (Figure 5). The drained area (2.5 m^2) had plastic slatted floors with urine drain (10 mm openings). The remaining solid area (4.5 m^2) consisted of solid concrete or solid concrete with a polyurethane coating. The original concrete floor was put in the farrowing unit in 1993. A Danish company, Nordic Stald Kemi did the polyurethane-floor construction in summer 2010 and the polyurethane material used in the study was a Mastertop 2-layer surface. The approximate thickness in total was 3 mm.

Figure 4. A picture of the farrowing pen (Jos Botermans).

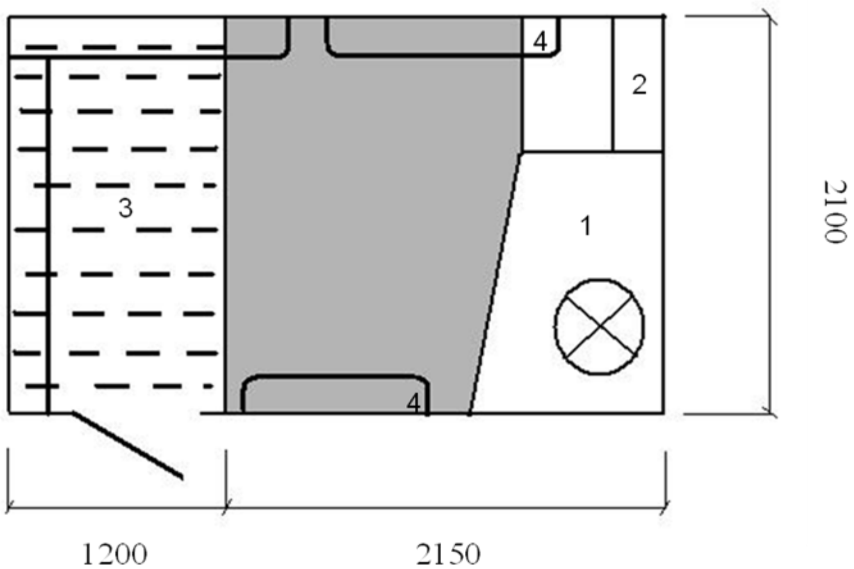


Figure 5. Schematic picture of the farrowing pens. 1: piglet creep area;
2: feed trough; 3: slatted floor; 4: fenders (all measurements expressed as mm).

4.1.1.1 The floor material

The existing old concrete surface was first cleaned and roughened with an angle grinder. A primer was put on top of the old concrete surface (Figure 6A) and then finally a “polyurethane mass” was put on top of the primer (Figure 6C). Two of the test pens used in this study had from the beginning floors with old plane unstructured polyurethane coatings. These pens had been used in an earlier study when a plane polyurethane coating was tested (Johansson, 2011). No preparatory work was done on the floor in these two pens and the new polyurethane mass was just put on top of the old polyurethane surface.

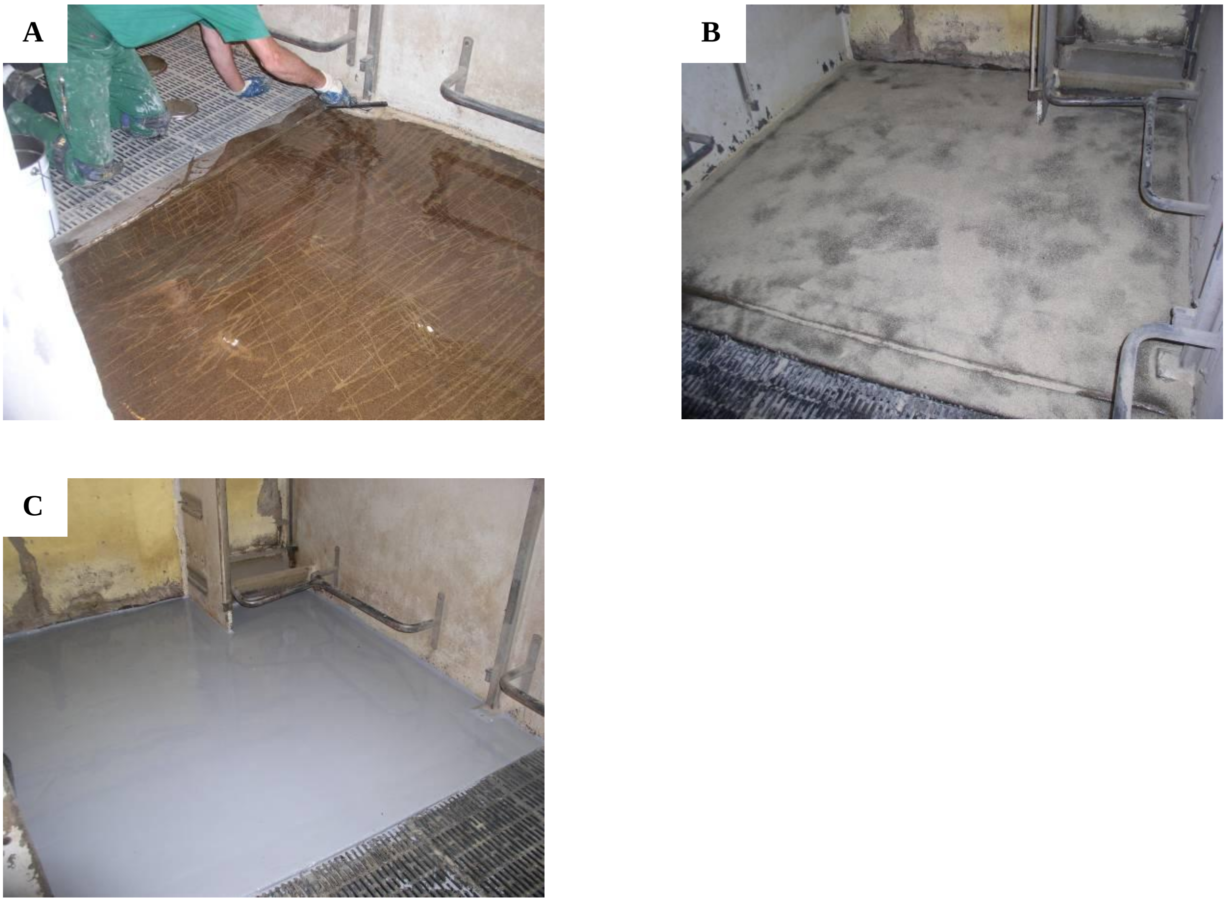


Figure 6. Pictures showing the construction of the floor with polyurethane coating. **A:** the primer has been put on top the old concrete; **B:** powder was spread on the primer; **C:** the polyurethane mass has been put on top of the primer (Jos Botermans).

The polyurethane mass was structured before drying to make a better floor grip, to reduce slips. Two different structure profiles were included in the study; corrugated profile, which was constructed by using a corrugated board (Figure 7A) and a profile that was constructed by using straw (Figure 7B). The corrugated board and straw was washed away when the polyurethane mass had dried of and a structure was remaining (Figure 7C and 7D).

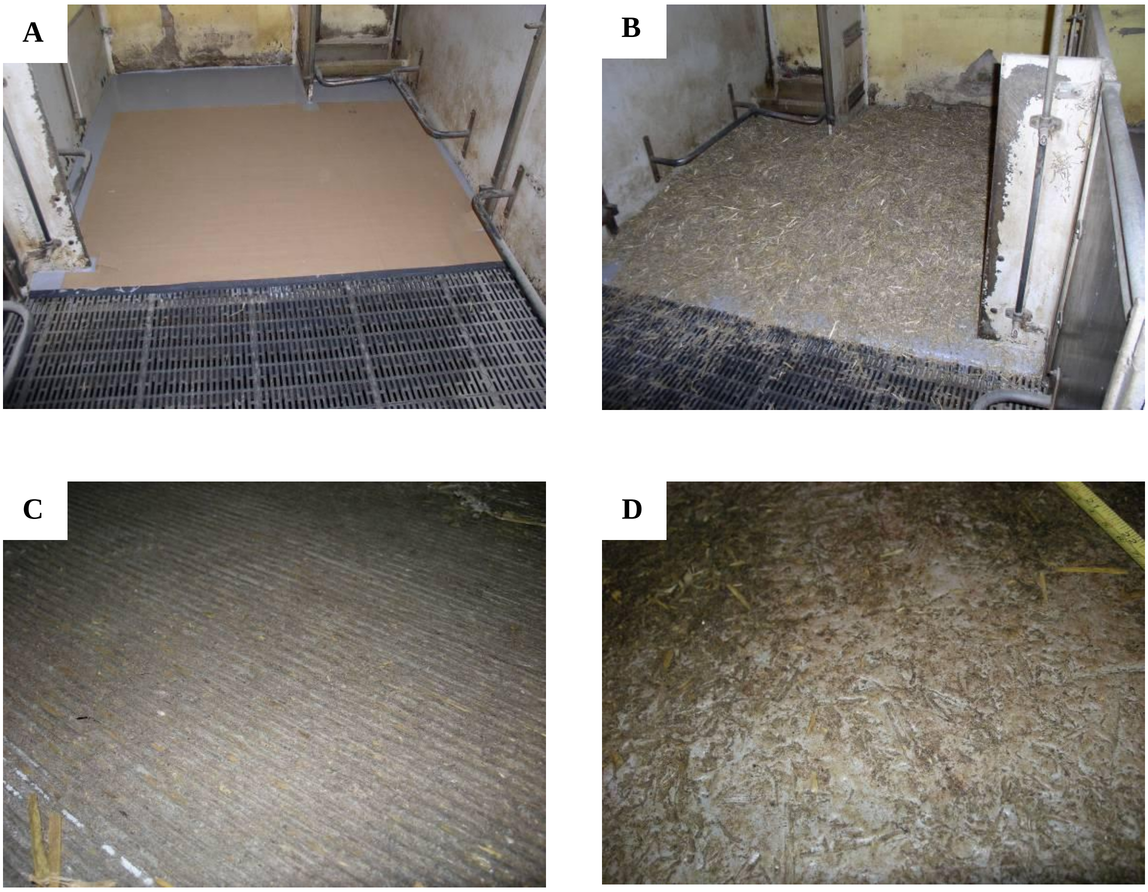


Figure 7.Pictures showing the formation of the two structure profiles
(A: corrugated; B: straw) (Jos Botermans) and the finished results (C: corrugated; D: straw).

4.1.2 Recordings

4.1.2.1 Examination of piglets' claws and legs

The piglets were individually examined approximately one week (2-10 days) post partum. The examination and scoring was done as a blind test, in a separate room. The person conducting the scoring did not know on which floor the piglet was reared on. The piglets' were examined for presence of claws and skin lesions according to a protocol mainly composed of the Swedish animal health service. The protocol had been moderated to suit this study (appendix 1). The piglets' feet were cleaned with a damp sponge and a scoring of injuries on each piglet was done. The total scoring was depending on how much injuries the piglet had at the time of examination. The soles were checked if they were rounded or not and the scoring for rounded soles were maximum 8 points given if all soles were rounded. If no sole was rounded the piglets received a score of 0. Other examined injuries were injuries on: sole (max 8 scores/piglet), soft heel (max 8 scores/piglet), coronet (max 8 scores/piglet), accessory digit (max 8 scores/piglet), fetlock (max 2 scores/piglet), knee (max 2 scores/piglet) and hock (max 2 scores/piglet). The diameter (mm) of each knee injury was measured and a mean value was calculated for each piglet. If the piglet did not have any knee damage, the diameter was registered as 0 mm. Only the injuries where the skin of the sole and soft heel was pierced was scored as injured. The piglets were also examined for redness of the soft heel (max 8 scores/piglet), claw abscess (max 8 scores/piglet), lameness (max 1 score/piglet), and inflammation of joint (max 4 scores/piglet). Damage of the piglets' legs made by the sow was also recorded (max 8 scores/piglet) and damaged teats (max 1 score/piglet) as well as registration on antibiotic treatment (max 1 score/piglet). Examples of the injuries scored can be seen in figure 8 (a-e).

The selection of control litters that were reared on concrete floor were matched with those of litters reared on polyurethane coatings. The litters were matched for age, litter size and parity number of the sow.

Figure 8a. (left) fore limbs with skin abrasions on knees and fetlocks. (right) Bruising on the sole of the claw of a preweaning piglet.

Figure 8b. Damage on a preweaning piglet caused by the sow.

Figure 8c. Injured soft heel of the claw of a preweaning piglet.

Figure 8d. Claw abscess.

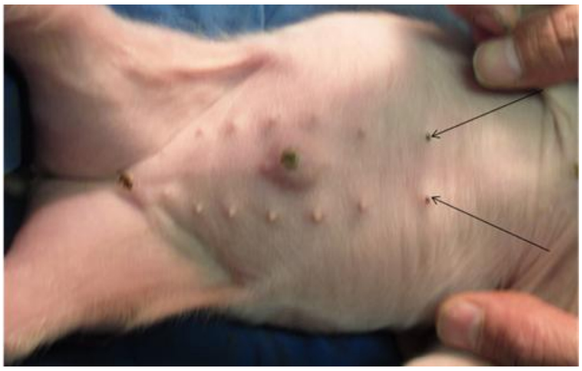


Figure 8e. Damage on teats of a preweaning piglet.

4.1.3 Floor tests

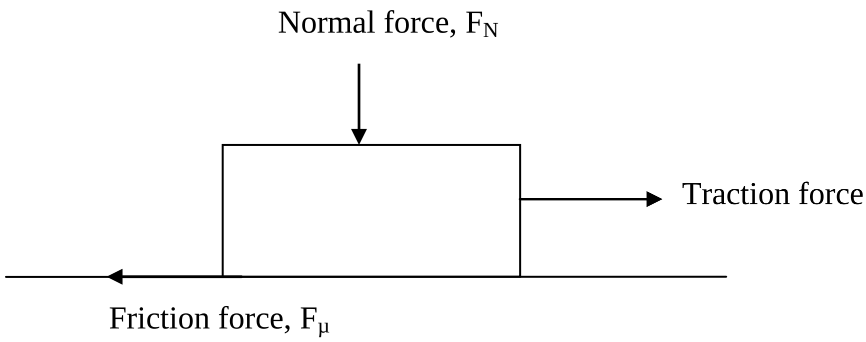
4.1.3.1 Friction testers-laboratory tests

The reason for testing the friction was to obtain a value of how slippery the polyurethane coatings in the study were. Two different test devices were used in the study:

1) A horizontal pull slip meter (PSM) (Figure 9), designed at the Department of Rural Building, Alnarp, was used on the polyurethane coating, both on the corrugated- and the straw structured. It was unfortunately not possible to transfer the PSM-tester to the research farm, because of the large size and all adjustments done on the PSM. That made it impossible to make friction tests on the existing old concrete floor used in the study. Instead friction measurements from the literature were used as references values.

Figure 9. The PSM friction measurement device. (Hans von Wachenfelt)

The PSM-tester has a hydraulic piston that pulls the test body horizontally and the force required to pull it was recorded by a PSM-sensor placed between the piston and test body. The ratio between the total vertical (normal) force and the pulling force was calculated as SCOF and DCOF (Figure 10). SCOF occurred when the test body was at rest and set in motion and DCOF when the test body was moving. The PSM-tester has been calibrated four times with known weights according a calibration curve (von Wachenfelt, 2011).



$$\mathbf{F_{\mu} = COF \times F_N}$$

Figure 10. A schematic picture showing the relationship between the normal, traction and friction force.

2) A Skid Resistance Tester (SRT) (Figure 11) was used to measure the friction of the floor with polyurethane coating with a corrugated structure. The friction was tested in the same directions as the grooves and transverse the grooves. The SRT measures the energy loss when a rubber-test body (placed at the end of the pendulum) slides over the floor surface. The value of friction is measured in British Pendulum Number (BPN). Ten swings each in both directions (with and transverse the grooves) were done. The results were presented as means of the ten values obtained. The SRT friction measurement device could not be used on the test floor with a straw structured profile. The test floor piece for the straw structured polyurethane coating was bulging and it would give an incorrect result.

Figure 11. The SRT friction measurement device. (Hans von Wachenfelt)

4.1.3.2 Abrasive measurements-field tests

The reason for measuring the abrasiveness was to obtain a technical value of the wear of the floors. The abrasive measurements were carried out at LBT's Odarslöv's Research Farm. The measurements were done in three different farrowing pens, one with the old original concrete floor, one with straw-structured polyurethane coating and one with the corrugated-structured polyurethane coating. The method used when measuring the abrasiveness has been developed by Nilsson (1988) and is including a block of plaster. The plaster block (water/gypsum- ratio =0.65) was dragged a distance of 10 m over the floor surface and three measurements on each floor were done, giving a mean value expressing the abrasiveness of the floor. Three plaster blocks for each floor were formed and a new block of plaster was used in all measurements. The plaster block was weight before the test and weight again after the test and the weight-loss was calculated. The more weight-loss, the higher value of the wear of the floor is obtained. The weight of the plaster blocks (including loading weight) was 2.100 kg (Figure 12). The floor contact area was 113.0 cm^2.

Figure 12. Plaster block including loading weight.

4.1.4 Statistical analysis

The results from the scoring of piglets' claw- and leg damages were registered in Microsoft Office Excel and means for each pen were calculated. The statistical analyses were performed on these pen-means, by using the SAS software (version 9.2, SAS Inst. Inc.). In the first step, means and standard deviations were calculated by using proc MEANS. After correction for the different floor profiles, all residuals were checked for normally distribution with proc UNIVARIATE. Seven of the parameters were normally distributed and these parameters were: red soft heel, diameter of knee damage, soft heel, fetlock, hock, damage cause by the sow and treated piglets. For analysing variation of these parameters analysis of variance, proc GLM was used. Proc npar1way wilcoxon was used for analysis the variation of the parameters that were not normally distributed and these parameters were: rounded soles, sole, coronets, accessory digits, knee, claw abscess, joint inflammation and teats. The Chi-square test was used to determine if there were differences between the four floors, concrete, straw structured polyurethane coating and the damaged and undamaged corrugated polyurethane coatings. If there were differences between floors, pair-wise tests were performed between the different floors using a Wilcoxon test. The hypothesis in this thesis was that piglets reared on structured polyurethane floors had fewer claw- and leg lesions than piglets reared on concrete (one-sided test). In the floor measurements (the abrasion and the friction tests), means and standard deviations were calculated by using proc MEANS. For analysing the variation in these measurements between concrete, corrugated polyurethane, damaged corrugated polyurethane and the polyurethane coating with straw structure, proc GLM was used.

To analyse the variation between concrete and polyurethane the statistical models used was:

$$\mathbf{Y_{ij} = \mu + f_i + e_{ij}}$$

Where:

Y_{ij} =observation per pen$_{ij}$

μ = average mean

f_{i} = floor effect (i = 1,2,3,4)

e_{ij}= residual

Significance levels:

ns (non-significant) $p > 0.10$

tendency $0.05 < p \leq 0.10$

*	$0.01 < p \leq 0.05$
**	$0.001 < p \leq 0.01$
***	$p \leq 0.001$

The results are presented as mean and standard deviation.

5 Results

Two of the polyurethane coatings had a corrugated profile and one of the polyurethane coatings was straw structured. One of the polyurethane coatings (corrugated) used in the study was damaged by a sow in the beginning of the study. The farrowing pen had been used in an earlier floor study, which probably resulted in poor attachment of the new polyurethane mass. The sow succeeded to get a grip of the top layer of the polyurethane coating and destroyed it, which resulted in that the old polyurethane floor beneath was exposed in about one third of the pen. The injury and damage results from the three floors with polyurethane coatings were therefore expressed and statistically calculated separately from each other.

5.1 Recordings of claws and leg lesions

There were in total 247 piglets included in the study, in total 22 litters whereof 12 litters were reared on polyurethane structured floor and 10 litters on original concrete. All piglets (100 %) reared on concrete had rounded soles (Table 1). None of the piglets reared on polyurethane had any damage to their coronets. The concrete floor and the damaged polyurethane coatings gave 25 % and 18 % of the piglets' injuries on their hocks respectively; while pigs on the undamaged polyurethane coatings had a percentage of 5 (corrugated) and 2 (straw structured).

Table 1. Proportion of piglets (%) with injuries kept on the different floors

	Concrete	**Polyurethane**		
		Corrugated	Straw	Corrugated (damaged)
No. pens	10	4	4	4
No. pigs	116	40	47	44
Red soft heel	82	80	83	91
Rounded soles	100	90	66	89
Sole	9	8	0	7
Soft heel	37	30	9	39
Coronets	2	0	0	0
Accessory digits	3	3	2	0
Fetlock	40	50	40	25
Knee	96	98	87	91
Hock	25	5	2	18
Damage[1]	7	3	6	2
Claw abscess	3	0	2	2
Joint inflammation	3	5	6	0
Treated	7	5	9	0
Teats	4	0	2	0

[1)]Damage on claws and legs caused by the sow

Several of the piglets in the study had soft heels that were red but not pierced. Findings of red soft heel were therefore registrated as a parameter. However, piglets reared on polyurethane often had brown coloured soft heels (Figure 13). The brown colour was never seen in piglets reared on concrete.

Figure 13. Brown coloured soft heels on piglet reared on polyurethane (Jos Botermans).

Piglets reared on polyurethane coatings had significantly fewer rounded soles ($p<0.01$) and there were also fewer pigs with injuries on their hocks ($p<0.05$), compared with piglets reared on concrete floor (Table 2). There was also a tendency ($p<0.10$) that piglets reared on the polyurethane coating with straw structure had more damages caused by the sow than piglets reared on the two other polyurethane coatings with corrugated structure. No other significant differences in injuries were detected between the different floors.

Table 2. Pen mean (± standard deviation) of scores of claw and leg lesions in preweaning piglets on the different floors and significance level

		Polyurethane				
	Concrete	Corrugated	Straw	Corrugated (damaged)	P-value	Sign. level
No. litters	10	4	4	4		
Average litter size	11.6	10.0	11.8	11.0		
Average age	6.6	5.3	6.3	6.3		
Red soft heel	4.66 (± 2.19)	3.91 (± 1.29)	4.97 (± 1.92)	4.94 (± 0.78)	0.4161	ns
Rounded soles	6.96[a] (± 1.22)	3.93[b] (± 2.04)	3.17[b] (± 2.21)	3.98[b] (± 1.95)	0.0014	**
Sole	0.11 (± 0.12)	0.09 (± 0.13)	0.15 (± 0.31)	0.09 (± 0.67)	0.3515	ns
Soft heel	0.69 (± 0.50)	0.50 (± 0.77)	0.23 (± 0.32)	0.74 (± 0.88)	0.2918	ns
Coronets	0.02 (± 0.63)	0.00 (± 0.00)	0.00 (± 0.00)	0.00 (± 0.00)	0.3765	ns
Accessory digits	0.06 (± 0.11)	0.02 (± 0.05)	0.00 (± 0.00)	0.00 (± 0.00)	0.2191	ns
Fetlock	0.62 (± 0.39)	0.70 (± 0.40)	0.73 (± 0.66)	0.50 (± 0.30)	0.4390	ns
Knee	1.81 (± 0.16)	1.81 (± 0.17)	1.69 (± 0.47)	1.64 (± 0.12)	0.1910	ns
Diameter of knee damage (mm)	11.1 (± 2.25)	10.5 (± 2.86)	10.5 (± 4.00)	9.4 (± 1.21)	0.3672	ns
Hock	0.38[a] (±0.23)	0.09[b] (± 0.18)	0.07[b] (± 0.78)	0.27[ab] (±1.22)	0.0186	*
Damage[1]	0.06[ab] (± 0.04)	0.02[a] (± 0.04)	0.09[b] (± 0.07)	0.02[a] (±1.22)	0.0788	+
Claw abscess	0.03 (± 0.06)	0.00 (± 0.00)	0.03 (± 0.06)	0.02 (±1.22)	0.3916	ns
Joint inflammation	0.03 (± 0.05)	0.05 (± 0.05)	0.05 (± 0.06)	0.00 (±1.22)	0.1958	ns
Treated	0.07 (± 0.06)	0.07 (± 0.09)	0.09 (± 0.11)	0.02 (±1.22)	0.3090	ns
Teats	0.06 (± 0.08)	0.00 (± 0.00)	0.04 (± 0.08)	0.11 (±1.22)	0.2267	ns

[1)] Damage on claws and legs caused by the sow

[a)] and [b)] = different letters shows that there is a significant difference between the floors

Limits for statistical significance: ns (not significant) p>0.10 ; + tendency where p<0.10; * p<0.05; ** p<0.01; *** p<0.001

5.2 Floor measurements

5.2.1 Friction tests

5.2.1.1 Drag test

The results from the drag test are presented in table 3 as coefficients of static friction (SCOF) and dynamic friction (DCOF), as means and standard deviations. The two polyurethane coatings had the same SCOF means (0.64). The SCOF means from this study were similar with one SCOF mean of concrete, 0.67. The SCOF means from the different concrete measurements differed a lot. Two of the SCOF means from the concrete measurements were much lower (0.38 and 0.37) than the means for the polyurethane coatings.

Table 3. The coefficients of static friction (SCOF) and dynamic friction (DCOF) and standard deviations

Floor	**N**	**SCOF**	**Std**	**DCOF**	**Std**	**References**
Polyurethane, straw	13	0.64	0.07	0.38	0.03	Own results
Polyurethane, corrugated	7	0.64	0.05	0.36	0.01	Own results
Concrete	10	0.67	0.06	0.65	0.05	Thorup et al., 2007
Concrete	un	0.38	0.014	0.32	0.14	Nilsson et al., 2008
Concrete	10	0.74	0.06	0.63	0.04	von Wachenfelt et al., 2009
Concrete, slats	un	0.37	0.010	0.29	0.010	Nilsson et al., 2008

N = number of observations

un= number of observations unknown

5.2.1.2 Skid resistance test

The results from the skid resistance test are presented in table 4, as mean values calculated from 10 measurements. The mean value from the polyurethane coating, toward the grooves, was higher (110 BPN) than the polyurethane coating, with the grooves (80 BPN). No measurements could be done on the polyurethane floor with straw structure as the test floor was bulging, which made it impossible to get a correct value.

Table 4. Mean values for the skid resistance test on the corrugated polyurethane floor structure expressed as British Pendulum Number (BPN)

Floor	**N**	**Skid resistance, BPN**
Polyurethane corrugated, transverse the grooves	10	110
Polyurethane corrugated, same direction as the grooves	10	80

5.2.2 Abrasion tests

There was a significant difference ($p<0.001$) between the mean values of the two undamaged polyurethane coatings used in the study, compared with the original concrete floor (Table 5). The mean from the original concrete floor shows the highest value of 0.91 g/10m. The two polyurethane coatings had means of 0.37 g/10 m (straw) and 0.30 g/10 m (corrugated) respectively. The two floors with polyurethane coatings showed no significant differences in between.

Table 5. Mean values and standard deviation for abrasion tests done of the undamaged corrugated polyurethane floor, the straw structured polyurethane floor and the original concrete floor.

Floor	N	Abrasion[1)]	Std
Concrete	3	0.91	0.05
Polyurethane, straw	3	0.37	0.10
Polyurethane, corrugated	3	0.30	0.01

1) Mean value (g/10m)

6 Discussion

The aim of this thesis was to analyse at the presence amount of injuries in preweaning piglets caused by the floor material. The major object was to detect large differences between the piglets reared on different floor materials. It was expected that the floors with polyurethane coatings would reduce all injuries towards zero. Therefore, to continue further research of this type of polyurethane material as floor material in farrowing pens, the results of this thesis need to show large differences. The aim was not to get any knowledge about when the injuries arose, nor if piglets' front or the back legs and claws were more or less affected. Neither if there were any differences between genders.

The following discussion will bring up the main results from the examinations of the piglets' injuries and from the floor measurements, followed by a general discussion about the polyurethane material, considering slips and ease of cleaning.

6.1 Injuries

6.1.1 Knee and hock damage

The results from this thesis confirm earlier studies, that knee injuries are commonly occurring among preweaning piglets. All floors in the study gave a remarkable high percentage of knee damaging, where the corrugated polyurethane had the highest prevalence (98 %) and the straw structured polyurethane coating the lowest (87 %). It would have been desirable to find significant fewer knee injuries in piglets reared on polyurethane coating, than in piglets reared on concrete. This was unfortunately not the case whereas the scores from piglets reared on polyurethane and concrete were equivalent. Gravås (1979) investigated the effect of the floor material on the diameter of the knee damage in piglets. In his study, rubber floors gave a large diameter on the wounds on piglets' knees, while concrete gave small wounds. In this study, the diameter of the knee damage was similar between the piglets, regardless which type of floor surface material they were reared on. It would have been desirable to get smaller diameter of the knee damaging when using the softer polyurethane material but no difference in size could be seen in this investigation. It was thought that the structure would, due to better floor grip, prevent piglets from sliding, so that they would not have to paddle with their front legs as much during nursing time. A thought is that these knee damages may have come from friction, instead of scrubbing and wearing as is does when rough concrete is used as floor material. It may be that the only solution for decreasing the amount of knee damages is to use straw or some other kind of litter in farrowing pens. If the floor itself cannot cope with the floor requirements, extra material like straw must be added (Baxter, 1984).

This study found that there were significantly fewer ($p<0.05$) hock damages on piglets reared on undamaged polyurethane coating, compared with concrete. Only 2 % and 5 % of the piglets reared on polyurethane surface, straw and corrugated respectively had damage on one or both hocks. The concrete floor gave a relatively higher amount of hock damages as 25% of the piglets reared had damage to their hocks. This can be a result from rubbing the tissue against the rough concrete. The reason that the damaged polyurethane coating gave a high percentage of piglets with hock damages may be that some underlying old polyurethane was exposed.

6.1.2 Damage to sole and soft heel

In earlier studies, Baxter (1984) and KilBride et al. (2009a) discuss that injuries to sole and soft heel may be a portal for microorganisms to enter and cause infections. In this thesis, the softer polyurethane material was supposed to give fewer injuries than rough concrete and thereby avoid unnecessary infections, but no significant differences could be distinguished. It is possible that the structure of the polyurethane surface had an influence due to irregular floor contact with the claw. The pressure from the floor is thereby unevenly distributed and may cause damage to the tissue. When scoring sole and soft heel injuries, only piglets where the skin was penetrated were scored as injured. Numerous piglets had skin that was changed in some other kind of way. Piglets reared on concrete often had red soft heels and piglets reared on polyurethane material did not have red soft heels like piglets reared on concrete, but brown coloured soft heels.

There was however a significant difference ($p<0.01$) in prevalence of rounded soles between piglets reared on polyurethane coatings and piglets reared on concrete. Many of the piglets reared on polyurethane did have sharp-edged soles and while all piglets reared on concrete had rounded soles. This may be due to the rough concrete surface that probably wears the tip of the sole.

6.1.3 Injuries to the coronets

There was a difference in prevalence injuries to the coronets to some extent, depending on which floor material the piglets were reared on. None of the polyurethane coatings gave any damage to the piglets' coronets while 2 % of the piglets reared on concrete had injuries.

6.1.4 Damaged teats

There was a small but not significant difference in proportion of piglets with damaged teats. About 4 % of piglets reared on concrete and 2 % of piglets reared on straw structured polyurethane had damaged teats. It was always the front teats that were damaged which also has been found by Penny et al. (1971). A reason for this may be that the other teats are hidden and protected in some way. None of the piglets reared on the two floors with corrugated polyurethane coatings did have any damaged teats at all.

6.1.5 Slip related damaging

Damage to the piglets caused by the sow may be the result of a slippery floor. It is easier for the sow to control her movements and avoid hurting the piglets if the floor grip is adequate. The sow herself can however be a risk depending on how limber and precautious she is but a slippery floor may aggravate the situation even more. If the sow slips and the piglets are unobservant it is most likely that a piglet will get hurt in some kind of way. There was a tendency ($p<0.10$) that piglets reared on polyurethane coating with corrugated structure had less damage caused by the sow than those reared on straw structured polyurethane. It seems that sows had a better grip on the corrugated structure than on the straw structured polyurethane.

6.2 Floor measurement

The polyurethane material in this study was given a profile to create a better floor grip. Two different structures in the polyurethane material were tested and compared with the original concrete floor used in the farrowing pens. The polyurethane coating was tested in an earlier project performed in the research herd, where the polyurethane was plane and unstructured. The floor in the earlier project became very slippery and there seemed to be a problem with slips, crushed piglets and piglets with splay legs (Johansson, 2011). The staff at Odarslöv did notice that the pigs in this study did not slip as much when the polyurethane is structured, as they did during the previous floor study, which is a satisfying result.

6.2.1 Friction

6.2.1.1 Pull slip meter

The optimal would have been to move the PSM-tester to Odarslöv and test the concrete floor and polyurethane floor used in the study, but it was not possible due to the large size of the equipment. Therefore only laboratory test was done on the polyurethane coatings. Both the corrugated and straw-structured polyurethane had a SCOF mean of 0.64 which is similar to the SCOF results from some earlier measurements of concrete. Thorup et al. (2007) and von Wachenfelt et al. (2009) showed SCOF means from concrete measurements of 0.67 and 0.74 respectively. The polyurethane with a corrugated profile in this study had a DCOF mean of 0.36 and the straw structure a DCOF mean of 0.38. Both these values are lower than DCOF means of concrete in earlier studies of Thorup et al. (2007) and von Wachenfelt et al. (2009) where the results were 0.65 and 0.63 respectively. However, results from concrete vary a lot depending on how rough and worn the surface is. Moreover did Nilsson et al. (2008) show a similar DCOF value from concrete (0.32) as the DCOF values received from the polyurethane floors. The variation between SCOF and DCOF values for concrete is generally small. The variation between SCOF and DCOF values for polyurethane is much higher than the variation of concrete presumably because the test body on irregular polyurethane structure needs a higher force to get the test body into movement.

6.2.1.2 Skid resistance test

The skid resistance test was only performed for the polyurethane coating with a corrugated profile. This test was done as a laboratory study and performed to bring out the variation in friction of the structure when measuring the friction in the same direction as the grooves and measuring the friction transverse the grooves. The results showed a variation of 80 BPN and 110 BPN respectively. Jordbruksverket (2006) suggested that the BPN value in farrowing pens should be at least 80, which the corrugated structure in this study implemented in both directions. This testing device is however not optimal when testing structured floors, as the testing device is constructed to measure plane surfaces.

6.2.2 Abrasiveness

The abrasive tests were done on the concrete floor used in the study and on the two floors with undamaged polyurethane coatings. To give all floors and tests the same conditions, new plaster blocks were used for every measurement and weights were used to give all plaster blocks the same weight. There was a significant difference (<0.001) between the concrete floor and two polyurethane floors. The concrete did wear off much more weight from the plaster blocks than the polyurethane material did, regardless the type of floor structure. The polyurethane material should according to these results be more gentle to the piglets' tissue.

6.2.3 Differences between the structured profiles

Piglets reared on the polyurethane coating that was straw structured, had fewer lesions and abrasions of sole and soft heel, compared with those reared on corrugated polyurethane suggesting that this profile is gentler against piglets' claws and legs. However, piglets reared on the corrugated polyurethane coating did have fewer injuries caused by the sow. This may indicate that the corrugated profile gives the sow a better floor grip. The laboratory tests did not give any significant differences in friction between the corrugated and the straw structured polyurethane coatings.

6.2.4 Correlation between physical and biological parameters

The polyurethane coatings seem to be more gentle towards piglets' tissue according to the abrasion test. Due to the scoring of injuries on the piglets reared on polyurethane coating however, could not a lower number in diameter of knee injuries be detected. Moreover was not the occurrence of knee damages scored lower on piglets reared on polyurethane coatings compared with those reared on concrete. When calculating the percentage of piglets with injuries reared on the different floor types, could however some differences be detected, even if they in some cases were small and not significant. When comparing the floor with polyurethane coating that was straw structured, compared with concrete floor, most of the parameters had a lower proportion of piglets with injuries on the straw structured polyurethane. Except for red soft heel and damage to fetlocks, the parameters that had a higher or fairly the same proportion of piglets reared on straw structured polyurethane compared with those reared on concrete were mainly slip related injuries. All piglets reared on concrete had rounded soles while only 66 % of piglets reared on straw structured polyurethane had rounded soles on their claws. Moreover, none of the piglets (in proportion) reared on the straw structured polyurethane have any damaging on their soles, compared with 37 % of the piglets reared on concrete. Only 9 % of the piglets reared on straw structured polyurethane had injuries on their soft heels, while 37 % of piglets reared on concrete had damage to their soft heels. It seems like the straw structured polyurethane coating is gentler towards the piglets' claws, even if the differences in most cases are not significant. The floor with a corrugated polyurethane coating did not show the same low percentage of injuries as the straw structured polyurethane did. It may be that the corrugated profile of the floor resulted in an unevenly distributed pressure toward the claw and tissue which caused damaging. The two polyurethane coatings did according to the friction tests have SCOF and DCOF means similar to those of concrete. The corrugated profile however did have significant fewer damaging on the piglets caused by the sow, compared with the straw structured polyurethane. It may be that the structure of the corrugation gives the sow a better floor grip. A sow's claws are probably pressured differently in to the polyurethane material compared with the test body used in the PSM-tester.

6.3 General discussion

Four batches with 247 piglets is a small sample. It would have been desirable to group the three polyurethane floors together as one in the analyse, but there were too many differences between the three different polyurethane coatings, to be able to do that.

There may be a bias in the results from the damaged corrugated polyurethane coating, as the old and slippery polyurethane floor underneath from a previous study was exposed. The importance of a good preparation work before the polyurethane mass is put in, was noted. The incident with the polyurethane coating that became damaged by the sow, could probably been avoided if the preparatory work had been done properly. This shows the need of sufficient attachment of coating, as pigs are rooting and exploring all equipment inside their pen. If a sow finds a loose floor flap, she will probably tear and destroy the floor coating, as the snout of a pig is enormously powerful.

The age span between the piglets examined was between 2-10 days, since it was not possible to score the piglets at a specific age. It was not possible to get all sows to farrow at the same day and since the scoring was performed during only one day for each batch, an age span was the result. Lesions develop gradually with mild lesions developing the first day after birth and at day 3-10 days of age, the lesions becomes moderate (Zoric et al., 2004; Mouttotou & Green, 1999). All litters in this study, except one, were within the age span for the development of moderate sole bruising and skin lesions.

For this study, the limiting factor was the time available. There could only be three observations on piglets reared on polyurethane coating in each batch, since only three pens had a floor with polyurethane coating. By prolonging the time of the study, more batches could have been included and more piglets could have been scored. Also, the polyurethane coating that was damaged by the sow would have been excluded if the scoring was run over more batches.

It was not possible to identify any significant differences for most of the recorded damage scores on the concrete floor and polyurethane coatings. The first part of the hypothesis of this thesis was that the soft structured polyurethane coating gives less abrasions and lesions in preweaning piglets than the original concrete floor. This part of the hypothesis was thereby only partly fulfilled. The other part of the hypothesis that the structure gives the sow and piglets an adequate floor grip which prevents slips was presumably fulfilled. The staff confirmed that the sows did not slip as much as they did when the polyurethane surface was plane and unstructured. Only 2-3 % of the piglets reared on corrugated polyurethane had injuries caused by the sow while the concrete gave a percentage of 7 %. It might not be possible after all to get away from that the use of straw or some other type of litter is required to construct a comfortable floor, which minimizes the damaging caused by the floor.

This study did not investigate any difference in time of cleaning and drying, between different floor materials. However, the polyurethane surface should theoretically reduce both the cleaning and drying time. Concrete is a porous material and coatings can be used to decrease the water penetration into the concrete (Määtää et al., 2009). Therefore should the polyurethane material dry off faster compared with the original concrete floor.

7 Conclusions

In the present study a significant decrease in slip related injuries on piglets reared on profiled polyurethane coating could be seen. Furthermore, a significant decrease in hock damaging could be detected. The abrasion test showed that the abrasiveness of the polyurethane material, regardless the structure, was significant lower than the abrasiveness of the original concrete floor used in the study. The friction tests showed that the two polyurethane coatings had SCOF and DCOF means similar of those for concrete.

Injuries on piglets’ claws and legs have been a problem for decades. Even if some parameters in this study gave positive results, it seems hard to find the optimal floor. More floor studies need to be done and it is probably necessary to use a large amount of straw to decrease the amount of injuries on piglets’ claws and legs.

7.1 Future research

- More research on the polyurethane material as floor material should be done. A higher amount of piglets reared on the polyurethane coating, compared with piglets reared on concrete floors are needed in future studies. Moreover, is it favourable to score the piglets when they are of exactly the same age, since the injuries develop gradually.
- It would also be interesting to study if the cleaning and drying time differs between the polyurethane material and the concrete.

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Appendix 1

type of floor:	nr	red soft heel	rounded sole	diameter knee	sole	soft heel	coronary border	accessory digit	fet-lock	knee	hock	damage*	claw-abscess	joint	treated	lame	teats	comments
sow number:	1																	
farrowing date:	2																	
examination date:	3																	
age, days:	4																	
	5																	
	6																	
	7																	
	8																	
	9																	
	10																	
	11																	
	12																	
	13																	

* Damage on piglet’s claws and legs caused by the sow